UNITED STATES PATENT APPLICATION

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FOR

SPEAKER SYSTEMS AND METHODS HAVING AMPLITUDE AND FREQUENCY RESPONSE COMPENSATION

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BACKGROUND OF THE INVENTION

Field of the Invention

[0001] Generally, the present invention relates to the speaker systems and methods. More specifically, the present invention relates to a speaker systems and methods having amplitude and frequency compensation as a function of ambient noise.

Description of the Related Art

[0002] In the field of speaker system design and implementation, many factors play a decisive role in determine, for example, what types of speakers to use, how large the speakers should be, what frequency response the speakers should have, and so on. One of the more important off these factors is the environment in which the speakers must operate. Specifically, the frequencies and amplitudes of the ambient noise surrounding the speakers operational area must be considered.

[0003] Conventional speakers of today are utilized, for example, to present audio or audio/video advertisements in commercial and retail store environments where ambient noise levels may vary widely over time. It is known in the audio field that the intelligibility of reproduced speech or music sound in such environments, derived from an audio program signal, is strongly affected by the ratio of the volume of the reproduced sound to the volume of ambient noise. Intelligibility may therefore be enhanced by processing the audio program signal in such a manner as to vary the volume of the reproduced sound directly as a function of the volume of the ambient noise. Further, it is known in the audiology field that the intelligibility of a hearing aid microphone output signal containing both live speech and ambient noise signal components can be enhanced through a signal process that introduces both compressed gain and increasing high frequency feedback in response to decreasing amplitude of such speech and noise signal.

[0004] For example, U.S. Patent No. 3,934,084 to Munson describes an audio amplifier system that includes a variable gain amplifier adapted to receive an input signal, means for detecting periods when the input signal falls below a predetermined level, and sound transducer means arranged to provide a signal proportional to the sound level in the area or part

thereof covered by the system for controlling the gain of the amplifier. An inhibitor is provided which is arranged to be controlled by the detecting means so as to prevent any change of the gain of the variable gain amplifier except during periods when the input signal falls below the said predetermined level.

[0005] **Figure 1** illustrates a typical audio/video speaker system as is know in the art today. As shown in **Figure 1**, the audio program input signal $\mathbf{S_{in}}$, typically consisting of summed left and right stereo signals, is applied to signal input **s** of prior art signal process $\mathbf{P_1}$. $\mathbf{P_1}$ output port **o** provides signal process output signal $\mathbf{S_{out1}}$. $\mathbf{P_1}$ introduces transfer function $\mathbf{f_1}$ providing continually increasing gain of $\mathbf{S_{in}}$ with increasing amplitude of a signal process control signal described below. Microphone **MIC1** provides an output signal **S1** applied to level detector **D1**, which provides an output DC microphone signal **S2** applied to signal input **s** of electronic switch **E1**. $\mathbf{S_{in}}$ is also applied to level detector **D2**, which provides an output DC program signal **S4** applied to control input **c** of electronic switch **E1**. **S2** transfers to signal output **o** of electronic switch **E1**, providing signal process control signal **S3** only when DC program signal **S4** is in the off state, which occurs when $\mathbf{S_{in}}$ is below a minimum threshold level. **S3** is applied to control input **c** of signal process $\mathbf{P_1}$ and thereby determines transfer function $\mathbf{f_1}$.

[0006] Such conventional speaker systems provide amplitude compensation linearly and directly as a function of the changing ambient noise. This linear compensation is a transfer function $\mathbf{f_l}$ expressed by the equation $\mathbf{f_l}(S_{an}) = (S_{in} \times S_{an})$, where S_{in} is the program input signal amplitude and S_{an} is the ambient noise signal amplitude. However, the above linear transfer function is non-optimal for at least retail store and other commercial environments, which commonly exhibit frequent and widely varying changes in ambient noise, since the conventionally compensated speaker output signal provides commensurately frequent and widely varying changes in sound levels that can be annoying to listeners. Thus, what is needed is a speaker system providing direct, but incremental, amplitude compensation as a function $\mathbf{f_i}$ of such frequent and widely varying changes in ambient noise.

SUMMARY OF THE INVENTION

[0007] The present invention is a commercial speaker system in which the intelligibility of reproduced speech or music sound, derived from an audio program signal, is enhanced by means of at least one of a first and second transfer function of a signal process applied to such audio program signal, wherein the first transfer function incrementally varies the volume of the reproduced sound, for example in steps of 1 to 10 dB, directly as a function of the volume of ambient noise, and wherein the second transfer function incrementally or contiguously varies the high frequency response of the reproduced sound inversely as a function of the volume of the ambient noise. The ambient noise can be measured by a microphone, for example, located on or near the speaker system and can also be electronically averaged over a predetermined time period. The signal process provides an audio output signal that is applied to at least one amplifier and at least one speaker.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] These and other aspects and features of the present invention will become apparent to those ordinarily skilled in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures, wherein:

[0009] **Figure 1** illustrates a typical audio/video speaker system as is know in the art today;

[00010] **Figure 2** illustrates a first embodiment of an audio/video speaker system according to the present invention;

[00011] **Figure 3** illustrates a second embodiment of an audio/video speaker system according to the present invention; and

[00012] **Figure 4** illustrates a third embodiment of an audio/video speaker system according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[00013] The present invention will now be described in detail with reference to the drawings, which are provided as illustrative examples of the invention so as to enable those skilled in the art to practice the invention. Notably, the figures and examples below are not meant to limit the scope of the present invention. Where certain elements of the present invention can be partially or fully implemented using known components, only those portions of such known components that are necessary for an understanding of the present invention will be described, and detailed descriptions of other portions of such known components will be omitted so as not to obscure the invention. Further, the present invention encompasses present and future known equivalents to the known components referred to herein by way of illustration.

[00014] Equivalent variations of the signal process, circuitry and features of preferred and alternative embodiments of the present invention, including but not limited to the equivalent use of DSP or microcontroller circuitry to implement substantially the same functions, may be practiced without altering the basic principles of the present invention. Further, some functions of the present invention are described in terms of hardware and some as software. Such descriptions are merely for descriptive purposes and are not meant to limit the scope of the invention in any way. The present invention is not dependent upon a specific hardware or software implementation.

[00015] It has been determined in experiments conducted by the present inventor that the intelligibility of a reproduced program signal in the presence of widely varying ambient noise levels is substantially enhanced by a signal process with processing functions that are incremental, as opposed to contiguous, such that the volume of the reproduced sound does not change too frequently as a consequence of rapidly occurring large changes in the ambient noise. Such signal process can provide increasing gain and increasing high frequency response of the program signal as a function of decreasing amplitude of a microphone output signal comprising at least one of (a), ambient noise signal components without reproduced program signal components by enabling such microphone output signal only while the program signal is substantially off, which typically occurs between audio or audio/video advertisements, or (b) ambient noise with reproduced program signal components by enabling such microphone output

signal only while the program signal is substantially on, which typically occurs during audio or audio/video advertisements. The signal process parameters are maintained between such times as the microphone is enabled to provide continuing and stable sound reproduction.

[00016] An embodiment of the present invention is a commercial speaker system that receives an input audio program signal. The input audio program signal can be from any source, such as a CD, DVD, MPEG, tape, live broadcast, etc., and can consists a mono-signal or of summed left and right stereo signals. The speaker system of this embodiment can comprise a signal process and transfer function for enhancing the intelligibility of the reproduced program signal in the presence of widely varying ambient noise levels over discrete time increments. Such a transfer function can incrementally vary the volume of the reproduced sound, for example in steps of about 1 dB to about 10 dB, directly as a function of the volume of ambient noise, whereby such incremental variations ensure that the volume of the reproduced sound does not change too frequently as a consequence of rapidly occurring changes in the ambient noise. The ambient noise can be measured by a microphone or other similar sound input device, and can be located on or near the speaker system. Further, the ambient noise input can be electronically averaged over a predetermined time period.

[00017] The signal process of this embodiment can provide an audio output signal that might be applied to at least one amplifier and at least one speaker. The system provides and utilizes ambient noise signal components without reproduced program signal components by enabling the microphone signal while the program signal is substantially off, which might occur, for example, between audio or audio/video advertisements segments or between conversation or music segments. According to at least one embodiment of the present invention, these substantially off periods can be, for example as short as about 100 milliseconds (ms), but typically might be between about 100 to about 1000 ms. However such timing constraints can vary with the installation environment and design implementation. The signal process can be maintained unchanging between such times as the microphone signal is enabled to provide continuing sound reproduction.

[00018] **Figure 2** illustrates a first embodiment of an audio/video speaker system according to the present invention. As shown in **Figure 2**, the program input signal $\mathbf{S_{in}}$ is applied

to signal input **s** of signal process $\mathbf{P_2}$. $\mathbf{P_2}$ output port **o** provides signal process output signal **S5**. $\mathbf{P_2}$ introduces transfer function $\mathbf{f_2}$ providing incrementally increasing gain, for example, in steps of about 1 dB to about 10 dB, to $\mathbf{S_{in}}$ as a function of increasing amplitude of a signal process control signal, and vice versa, described below. This transfer function $\mathbf{f_2}$ can, for example, be a non-linear equation of the form $\mathbf{f_2}(S_{an}) = (S_{in} \times S_{anI})$, where S_{anI} is the ambient noise signal amplitude in increments of, for example, about 1 dB to about 10 dB. As will be evident to those skilled in the art, functions $\mathbf{f_2}$ may be effectively implemented through hardware, firmware, software or a combination thereof. Microphone **MIC1** provides an output signal **S1** applied to level detector **D1**, which provides an output DC microphone signal **S2** applied to signal input **s** of electronic switch **E1**. $\mathbf{S_{in}}$ is also applied to level detector **D2**, which provides an output DC program signal **S4** applied to control input **c** of electronic switch **E1**. **S2** transfers to signal output **o** of electronic switch **E1**, providing signal process control signal **S3** only when DC program signal **S4** is in the off state, which occurs when $\mathbf{S_{in}}$ is off or substantially off, for example, below a minimum threshold level. **S3** is applied to control input **c** of signal process $\mathbf{P_2}$ and thereby determines transfer function $\mathbf{f_2}$.

[00019] The signal process $\mathbf{P_2}$ of **Figure 2** is maintained between such times as the microphone output signal is enabled (that is, switched through to the control input of the signal process) to provide continuing sound reproduction using the previously determined ambient noise level or average of levels. Signal process output signal **S5** can be applied to first amplifier **A1** having output signal $\mathbf{S_{out2}}$ applied to first speaker **SPK1**. The specific amplification used can be determined based at least in part on the type of speaker used and the desired volume of the target listener. Where low frequency performance enhancement is also desired, **S5** can optionally be applied to low-pass filter **F1** having filtered output signal **S6,** which is applied to second amplifier **A2** having output signal $\mathbf{S_{out3}}$ applied to second speaker **SPK2**. According to one aspect of this embodiment, the cut-off frequency of low-pass filter **F1** might be approximately 400 Hz. However, a range of between about 100 Hz to about 600 Hz or more can also be effective for the present invention. In this manner, the output of the signal process is amplified by a first amplifier and optionally a second amplifier, the outputs of which are applied to the speakers. The speakers can be, for example, comprise a single speaker driver having a

diaphragm diameter not greater than substantially 100 centimeters (cm) and producing a wide-dispersion sound field.

[00020] **Figure 3** illustrates a second embodiment of an audio/video speaker system according to the present invention. As shown in **Figure 3**, the program input signal $\mathbf{S_{in}}$ is applied to signal input **s** of signal process $\mathbf{P_3}$. $\mathbf{P_3}$ output port **o** provides signal process output signal **S7**. $\mathbf{P_3}$ introduces transfer function $\mathbf{f_3}$ providing increasing high frequency response to $\mathbf{S_{in}}$ as a function of increasing amplitude of a signal process control signal, and vice versa, described below. This transfer function $\mathbf{f_3}$ can, for example, be a non-linear equation of the form $\mathbf{f_3}(S_{an}) = (S_{inHF} / S_{an})$, where S_{inHF} is the high frequency response signal. As will be evident to those skilled in the art, functions $\mathbf{f_3}$ may be effectively implemented through hardware, firmware, software or a combination thereof. Microphone **MIC1** provides an output signal **S1** applied to level detector **D1**, which provides an output DC microphone signal **S2** applied to signal input **s** of electronic switch **E1**. $\mathbf{S_{in}}$ is also applied to level detector **D2**, which provides an output DC program signal **S4** applied to control input **c** of electronic switch **E1**. **S2** transfers to signal output **o** of electronic switch **E1**, providing signal process control signal **S3** only when DC program signal **S4** is in the off state, which occurs when $\mathbf{S_{in}}$ is off or substantially off, for example, below a minimum threshold level. **S3** is applied to control input **c** of signal process $\mathbf{P_3}$ and thereby determines transfer function $\mathbf{f_3}$.

[00021] The signal process $\mathbf{P_3}$ of **Figure 3** is maintained between such times as the microphone output signal is enabled (that is, switched through to the control input of the signal process) to provide continuing sound reproduction using the previously determined ambient noise level or average of levels. Signal process output signal **S7** is applied to first amplifier **A1** having output signal $\mathbf{S_{out4}}$ applied to first speaker **SPK1**. Where low frequency performance enhancement is also desired, **S7** is optionally applied to low-pass filter **F1** having filtered output signal **S8,** which is applied to second amplifier **A2** having output signal $\mathbf{S_{out5}}$ applied to second speaker **SPK2**. According to one aspect of this embodiment, the cut-off frequency of low-pass filter **F1** might be approximately 400 Hz. However, a range of between about 100 Hz to about 600 Hz or more can also be effective for the present invention. In this manner, the output of the signal process is amplified by a first amplifier and optionally a second amplifier, the outputs of

which are applied to the speakers. The speakers can be, for example, comprise a single speaker driver having a diaphragm diameter not greater than substantially 100 centimeters (cm) and producing a wide-dispersion sound field.

[00022] **Figure 4** illustrates a third embodiment of an audio/video speaker system according to the present invention. As shown in **Figure 4**, the program input signal $\mathbf{S_{in}}$ is applied to signal input **s** of signal process $\mathbf{P_4}$. $\mathbf{P_4}$ output port **o** provides signal process output signal **S9**. $\mathbf{P_4}$ introduces the combination of transfer functions $\mathbf{f_2}$ and $\mathbf{f_3}$. As previously described, above, $\mathbf{f_2}$ and $\mathbf{f_3}$ provide (a) incrementally increasing gain, typically in steps of about 1 to 10 dB, to $\mathbf{S_{in}}$ as a function of increasing amplitude of a signal process control signal, and vice versa, described below, and (b) increasing high frequency response to $\mathbf{S_{in}}$ as a function of decreasing amplitude of such signal process, and vice versa, described below, respectively. Microphone **MIC1** provides an output signal **S1** applied to level detector **D1**, which provides an output DC microphone signal **S2** applied to signal input **s** of electronic switch **E1**. $\mathbf{S_{in}}$ is also applied to level detector **D2**, which provides an output DC program signal **S4** applied to control input **c** of electronic switch **E1**. **S2** transfers to signal output **o** of electronic switch **E1**, providing signal process control signal **S3** only when DC program signal **S4** is in the off state, which occurs when $\mathbf{S_{in}}$ is off or substantially off, for example, below a minimum threshold level. **S3** is applied to control input **c** of signal process $\mathbf{P_4}$ and thereby determines both transfer functions $\mathbf{f_2}$ and $\mathbf{f_3}$.

[00023] The signal process $\mathbf{P_4}$ of **Figure 4** is maintained between such times as the microphone output signal is enabled (that is, switched through to the control input of the signal process) to provide continuing sound reproduction using the previously determined ambient noise level or average of levels. Signal process output signal **S9** is applied to first amplifier **A1** having output signal $\mathbf{S_{out6}}$ applied to first speaker **SPK1**. Where low frequency performance enhancement is also desired, **S9** is optionally applied to low-pass filter **F1** having filtered output signal **S10,** which is applied to second amplifier **A2** having output signal $\mathbf{S_{out7}}$ applied to second speaker **SPK2**. According to one aspect of this embodiment, the cut-off frequency of low-pass filter **F1** might be approximately 400 Hz. However, a range of between about 100 Hz to about 600 Hz or more can also be effective for the present invention. In this manner, the output of the signal process is amplified by a first amplifier and optionally a second amplifier, the outputs of

which are applied to the speakers. The speakers can be, for example, comprise a single speaker driver having a diaphragm diameter not greater than substantially 100 centimeters (cm) and producing a wide-dispersion sound field.

[00024] The present invention can be implemented a vast array of environments, too many to enumerate herein, but readily discernable by those skilled in the art in view of the foregoing discussion. As will further be evident by those skilled in the art in view of the present invention, the physical location of the components of the invention, including the relative locations of the components, might be dictated by each environment and can vary between environments. All of such use environments and physical implementations are meant to be within the scope of the present invention. For example, embodiments of the present invention might be used as part of a hands-free automobile cellular telephone system, where the ambient noise inside the automobile might change with varying automobile speeds and surrounding traffic. As another example, embodiments of the present invention might be used as part of a fast food restaurant drive-through ordering system, where the ambient noise at the ordering kiosk might vary according to weather conditions and the customer's automobile noise. As a further example, embodiments of the present invention might be used as part of a retail store, check-out line, advertising system, where the ambient noise at in the check-out line might vary with store crowdedness and customer conversations.

[00025] Although the present invention has been particularly described with reference to the preferred embodiments thereof, it should be readily apparent to those of ordinary skill in the art that changes and modifications in the form and details thereof may be made without departing from the spirit and scope of the invention. For example, those skilled in the art will understand that variations can be made in the number and arrangement of the components illustrated in the above block diagrams and that these components can be physically or functionally combined or divided to fit a particular application or environment. It is intended that the scope of the appended claims include such changes and modifications.